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NORTH DAKOTA...
CROP ROTATIONS FOR PROFIT

COOPERATIVE EXTENSION SERVICE
North Dakota State University
Fargo, North Dakota 58102

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For Use of County Extension Agents and Others In Furtherance of More Profitable Farm Management

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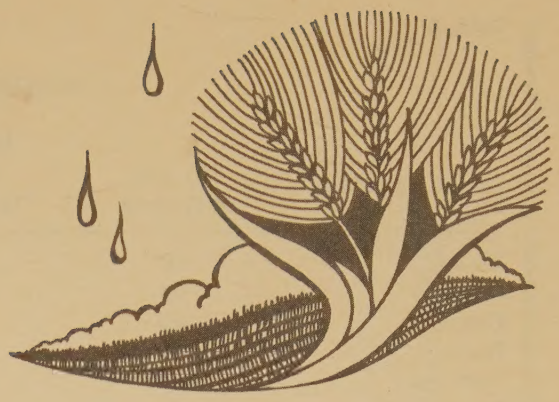


SECTION I.

LIMITATIONS AND BENEFITS OF ROTATIONS

Crop rotation is a planned order of crops grown in regular sequence on the same field. The purpose of rotations is to improve or maintain soil productivity and to reduce crop production hazards, thus maintaining higher average yields per acre. This should increase the level of economic return of the individual fields and of the farm unit as a whole. The number of profitable crops adapted to the climate and soils of North Dakota is limited, which makes rotations somewhat more difficult to plan and follow than in many other sections of the country.

CLIMATIC FACTORS LIMIT CROP CHOICE

The greatest limitation in choice of crops for crop rotations in North Dakota is imposed by climate.

The length of growing season varies from year to year but averages about 110 frost free days in the north central area along the Canadian border to over 130 days in the southeast corner of the state. See Figure 1.

The state has a variable and limited annual precipitation. See Table II and Figures 3 & 4. Fortunately for small grain crops which require a short growing season, nearly one-half of the total precipitation occurs during the growing months of May, June and July. See Table I. Even during this favorable rainfall season, the amount and distribution is usually less than adequate for high production. Drouth periods during the growing season are common either because the total rainfall is low or the time between rains is too long. Sometimes even when the subsoil is well supplied with moisture the loss of moisture from the growing crop during periods of stress caused by high temperature or wind exceeds the rate of moisture uptake by the roots and the crop suffers from water deficiency. This has an effect similar to drouth.

Temperatures are generally favorable for cool season crops through June but in some years may become too high during July before small grain crops mature. See Table I. Temperatures from November into March cause soil to freeze 4 to 5 feet deep or more depending on soil cover. See Table III. This severe winter freezing, especially when there is lack of snow cover and soil conditions are dry, along with alternate freezing and thawing in the spring, causes winter kill of all except the most hardy biennial or perennial crops. This limits most of the state to grain crops that are spring sown, except for winter rye. To take advantage of the most favorable growing season (May, June and July), spring sown crops must be able to sprout and grow in relatively cool soil temperatures. See Tables III and IV.

These North Dakota weather factors limit our choice of crops. The choice becomes progressively more limiting as we go from east to west and from south to north in the state.

Table I

North Dakota Average Monthly Weather Data 60 Years 1892-1951

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Av. Mean Temp.	7	10	24	42	53	62	68	66	56	44	27	12	40
Av. Max. Temp.	17	21	35	54	66	75	82	81	70	56	37	22	51
Normal Precip.	.48	.47	.79	1.44	2.33	3.52	2.43	2.09	1.54	.99	.61	.47	17.16
						8.28							

Source: Climate and Weather in North Dakota - 1952.

Table II

PRECIPITATION EXTREMES UP TO 1970

	No. Yrs. Of Records	No. Yrs. Below 12 Inches	No. Yrs. Below 16 Inches	Normal 1931-60	Greatest Annual	Least Annual
Ashley	58	3	14	16.78	30.42	6.60
Bowman	56	15	31	15.00	23.91	7.07
Bisbee	66	6	26	15.80	28.07	7.28
Bismarck	95	10	50	15.15	30.92	5.97
Bottineau	64	14	29	15.91	27.31	8.45
Carrington	72	6	27	17.46	25.27	6.52
Amenia	74	5	14	18.75	27.24	8.76
Cooperstown	73	2	23	18.23	28.63	9.85
Crosby	63	20	40	13.36	24.60	5.39
Devils Lake	94	7	33	16.98	25.39	10.29
Dickinson	78	13	40	15.42	31.16	6.72
Dunn Center	71	8	35	15.46	26.02	5.93
Edgeley	69	6	23	17.59	30.38	9.74
Ellendale	71	3	12	19.11	33.68	5.93
Fargo	89	3	11	18.45	34.48	8.87
Forman	78	2	10	19.73	35.51	9.06
Fort Yates	70	7	38	15.06	23.97	5.14
Grand Forks	79	2	12	20.12	29.57	9.38
Jamestown	78	5	21	17.76	29.80	6.91
Langdon	74	3	14	18.48	28.05	10.86
Minot	74	5	40	15.30	26.10	7.13
Napoleon	78	4	73	17.67	26.60	9.07
Steele	76	4	28	17.10	28.68	4.86
Towner	67	10	37	16.20	28.63	8.22
Wahpeton	78	2	10	20.59	36.29	10.74
Williston	91	19	62	13.70	22.04	6.13

Source: Ray E. Jensen, NOAA Climatologist for North Dakota, NDSU, Fargo

Table III

SOIL TEMPERATURE AT 3 INCH DEPTH

Fargo Station - 1962
Wheat Fall Plowed

	Degrees Fahrenheit		Degrees Fahrenheit		Degrees Fahrenheit
January 1-14	15.20	May 7-20	51.47	September 10-23	57.41
January 15-28	24.58	May 21 - June 1	54.58	September 24 - October 7	55.52
January 29 - February 11	19.45	June 2-17	65.55	October 8-21	54.22
February 12-25	21.76	June 18 - July 1	72.12	October 22 - November 4	40.95
February 26 - March 11	21.14	July 2-15	71.91	November 5-18	34.70
March 12-25	24.71	July 16-29	72.56	November 19 - December 2	35.32
March 26 - April 8	31.65	July 30 - August 12	74.69	December 3-16	28.20
April 9-22	33.75	August 13-26	71.88	December 17-30	22.81
April 23 - May 6	48.73	August 27 - September 9	63.85		

Source: Unpublished data from NDSU Soils Department

Table IV

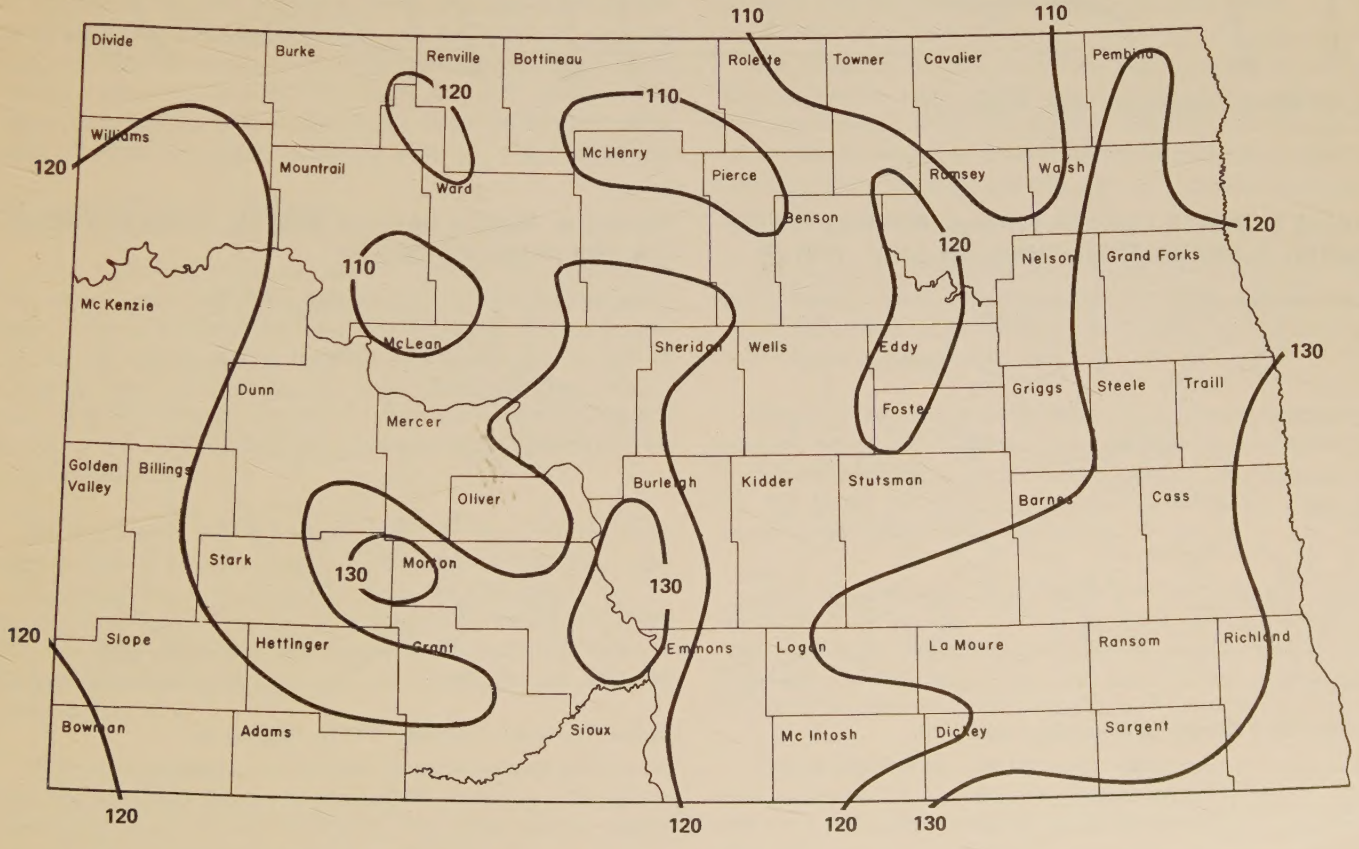
SOIL TEMPERATURES FOR GERMINATION

Crop	Degrees Fahrenheit Minimum or Threshold	Optimum Range
Clover	34 to 38	50 to 80
Alfalfa	34 to 39	50 to 80
Peas	38 to 40	45 to 70
Flax	38 to 40	59 to 65
Wheat	34 to 36	59 to 65
Barley	34 to 36	59 to 65
Oats	34 to 36	59 to 68
Rye	34 to 36	59 to 65
Sugarbeets	39 to 41	50 to 80
Potatoes	45 to 48	60 to 70
Beans	50 to 55	65 to 80
Corn	48 to 50	60 to 90
Sorghum	48 to 50	80 to 90

Source: Idaho Agricultural Science

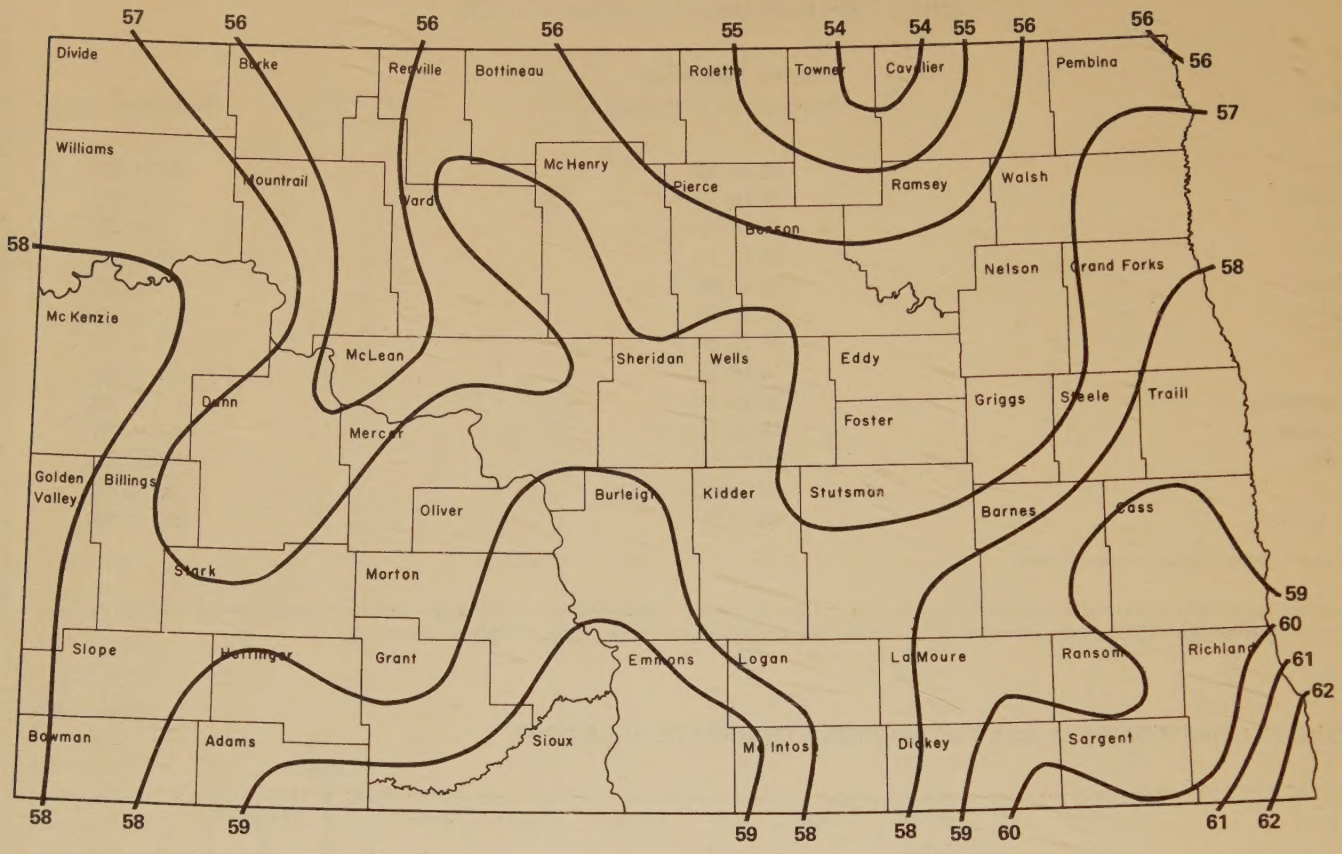
Germination is very slow and emergence requires a long time at the low temperatures. Germination speeds up progressively until the optimum range is reached. As temperatures go above the optimum range there is increasing damage to germination.

FIGURE 1. NORTH DAKOTA AVERAGE NUMBER OF FREEZE FREE DAYS



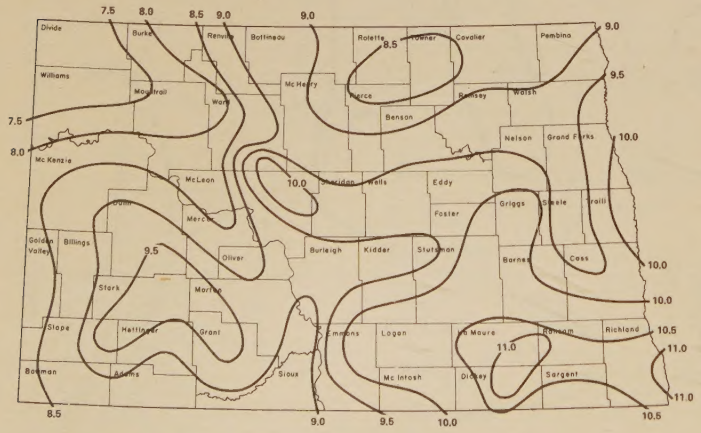
Source: The Probability of Freezing Temperatures - 1963, NDSU

FIGURE 2. NORTH DAKOTA ANNUAL NORMAL TEMPERATURE APRIL THROUGH JULY - 1931-60



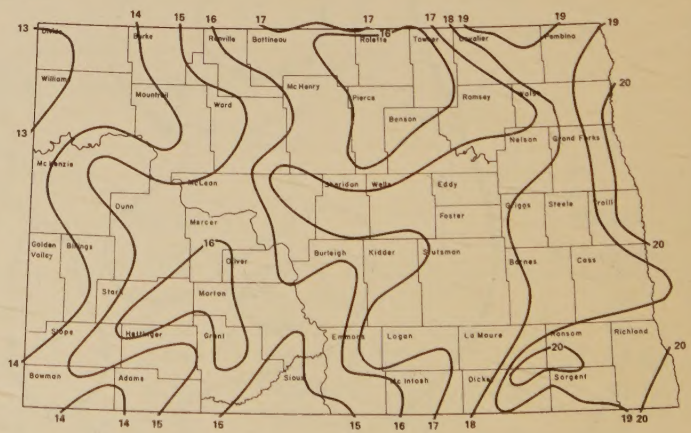
Source: NOAA Climatologist - NDSU, Fargo, N. D.

FIGURE 3. NORTH DAKOTA ANNUAL NORMAL PRECIPITATION IN INCHES APRIL THROUGH JULY - 1931-60



Source: NOAA Climatologist - NDSU, Fargo, N. D.

FIGURE 4. NORTH DAKOTA ANNUAL NORMAL PRECIPITATION IN INCHES 1931-60



Source: NOAA Climatologist - NDSU, Fargo, N. D.

SOIL FACTORS LIMIT CROP CHOICE

Further restrictions of crop choice are sometimes imposed by soil properties.

(1) Saline, saline alkali and alkali soils (see Section III)

(2) Drouthy soils - soils of low water holding capacity (see Section IV)

(3) Soils subject to flooding and poorly drained soils. Crop tolerance varies with length of time that saturated conditions prevail, stage of growth and nutritional level.

PROFITABLE MARKET VALUES LIMIT CROP CHOICE

To be of value in rotations, a crop must have either a direct or an indirect economic benefit to the producer. It must have yield capacity and a market demand that makes it profitable as a cash or a feed crop, or it must be a soil conserving or soil building crop which improves the physical and/or chemical property of the soil. Cover crops or green manure crops, for example, may have an indirect benefit to other crops.

ROTATIONS HAVE VALUE

In spite of the limitations on choice of crops, rotations can be of value in North Dakota. They may be helpful in reducing moisture loss; in controlling soil erosion, weeds, some plant diseases and some insects; in maintaining soil productivity; and in distributing labor loads. Usable rotations must be somewhat flexible to meet changing year to year situations.

PLANNING ROTATIONS

Crop rotations, of course, are confined to the cropland on the farm. Land that may have been cropped but has been seeded down permanently to grass for hay or pasture would not be included in a crop rotation plan except that it may be cropped temporarily to prepare for reseeding of grass. If such land is brought back into the rotation because of permanent shifts in the farming operations, it should be included in the rotation plan.

Most farms in North Dakota are too large to consider one rotation for the entire farm. The first step in planning rotations, therefore, is to divide the cropland into areas based on similarity of several factors and then plan a rotation suitable to each area. The more definite rotations and perhaps the shorter rotations will generally be planned for the best soil areas on the farm.

The more flexible and perhaps longer rotations will be for the less desirable soil areas and will be subject to change depending on year to year situations. For more specific suggestions on planning rotations, see Section IV.

Some of the more important factors that will influence division of the farm into rotation areas and that will determine rotations within these areas are:

1. Soil type as it may affect yield capacity or erosion problems.
2. Field topography, especially if it contains steep slopes or large potholes or flats subject to flooding.
3. Physical shape and condition of field such as influenced by streams, ditches, roads, rocks or shelterbelts.
4. Type of farming planned whether grain, livestock or mixed.
5. Distance of fields from farmstead.
6. Size of machinery to be used.
7. Weed control problems.
8. Labor distribution needs.
9. Size of farm and acreage control programs.
10. Cropping desires of the operator.

BENEFITS EXPECTED FROM ROTATIONS

The objective of crop rotations is to increase income per acre consistent with maintenance or even improvement of soil productivity. Crop sequences in the rotation must be set up so that crops or practices complement each other whenever possible. The following benefits can be expected from good rotations.

Moisture conservation is very important to successful crop production in North Dakota. Crop yields are influenced by stored soil moisture available in the spring, and by moisture received during the growing season.

Moisture that accumulates after an early crop is harvested benefits next year's crop on soils that have water holding capacity. A late maturing crop is more apt to leave the field with less stored soil moisture going into winter, and this is likely to decrease the yield of next year's crop.

Early planted crops that make their growth and mature during May, June, July or early August take advantage of the most favorable rainfall season. Lower temperatures during the early part of this period also are favorable for crop growth because of relatively low water loss from soil and plants.

Late planted crops, on the other hand, benefit from moisture accumulated in the spring before planting but in many years are filling and maturing when temperatures are unfavorably high and rainfall is low.

The practice of summerfallow usually stores some moisture from one growing season to the next and is, therefore, included frequently in the rotation in much of the state.

Weed control is a serious problem in continuous small grain production. Annual weeds generally can be controlled by good crop rotations and chemicals, but most perennial weeds must be controlled by special practices.

There are several good weed control rotation practices. Summerfallow encourages weed seed germination and prevents seed production; row crops such as corn, soybeans, sunflowers, potatoes and sugarbeets when kept free of weeds; delayed seeding of flax, millet and other crops permits weed control before planting; oats, millet or other crops cut for hay before weeds shatter seed; fall rye, especially when sown on fallow; grass and alfalfa alone or in mixtures cut for hay or silage or used for pasture are all good.

Soil productivity and tilth should be maintained. A good crop rotation including grasses and legumes and preserving annual crop residue (1) keeps the soil in good physical condition (2) helps maintain organic matter at least for short periods of time (3) legumes may add nitrogen and (4) changes the location of the feeding range of crop roots.

Sod crops such as grass and legumes may help maintain a good physical soil condition. Their extensive root systems add organic matter, which improves soil tilth and structure. Light sandy soils will retain more soil stored water and heavier loam and clay soils are loosened up so they will absorb water more easily, are easier to cultivate and puddle less. The organic matter supplied by these crops also adds raw food material for soil bacteria.

Legume forage crops such as alfalfa and sweetclover generally improve the productive level of the soil because of their nitrogen fixation and mellowing effect on soil. These crops, when harvested for hay, pasture or seed, usually add only enough nitrogen to take care of their own needs. Even when plowed down early it may be more practical to add nitrogen fertilizer to build up the fertility level.

Sod crops, because of their long growing season, deplete soil moisture reserves and may reduce yield of crops following in the rotation until soil moisture reserves are replenished. Alfalfa may dry the soil 15 to 20 feet deep, sweetclover 5 to 8 feet and perennial grasses 4 to 6 feet. For this reason they are not desirable except in very short rotations.

Annual legumes such as soybeans, field beans and peas do not deplete soil moisture as deeply as alfalfa and sweetclover and where adapted may have benefits in a rotation. They do not, however, build up an available supply of nitrogen for the next crop.

While crop rotation may be beneficial from a productivity standpoint, it should not be relied upon entirely. The intelligent use of farm manure and especially commercial fertilizers is needed to increase the productive capacity of most fields.

Erosion control must be attained. Where devices such as strip cropping, tree shelterbelts, contour farming and terraces are used to prevent wind or water erosion, the rotations must fit into these methods. Cropping practices and tillage methods are probably more important than rotations in erosion control. Sod crops in the rotation, especially grasses, are helpful on the better soils. Where erosion is serious, the fields should be seeded down permanently to sod crops.

Disease control is possible with the proper rotation of crops. Certain microorganisms that cause crop diseases survive in the soil from season to season on plant refuse. When susceptible crops are grown continuously, diseases can build up and become a serious problem. Resistant varieties and fungicides have made it possible to grow crops in a shorter rotation, but have not decreased the importance of using crop rotations for preventing a large build-up of plant disease.

Crop rotations are essential for controlling diseases caused by fungi and bacteria that do not survive long in the absence of their host plants.

Table V shows some of the more common crop diseases and the crops that are attacked. As much as possible, susceptible crops should not follow each other in a rotation, especially if a common disease is a problem.

Table V

COMMON DISEASES CONTROLLED ENTIRELY OR IN PART BY ROTATION

Disease	Crops Attacked[1/]
Common Root Rot	Wheat, barley, grasses
Ergot	Rye, wheat, grasses
Bacterial Blights	Wheat, barley, grasses, rye
Scab	Wheat, barley, corn, rye
Spot Blotch	Barley, wheat, grasses
Net Blotch	Barley
Septoria (different species)	Wheat, barley
Septoria (different species)	Wheat
Septoria (different species)	Barley
Pasmo	Flax
Rust (Flax)	Flax
Seedling Blight	Wheat, barley, corn, oats, rye
Smut (Corn)	Corn
Bacterial Wilt	Alfalfa
Crown Rot	Alfalfa
Verticillium Wilt	Potatoes, sunflowers
Rust (Sunflower)	Sunflowers
Tan Spot	Wheat, grasses

1/ Wheat includes durum

Insect control by crop rotation cannot be depended upon for combating all insects attacking field crops.

The number of general feeding insects that injure all cultivated crops grown in North Dakota is very small. Numerous insects feed on all the plants of one family and many feed on only very closely related plant species.

Wheat, barley and oats all belong to the grass family and when grown on the same land year after year are favorable to insects that attack this plant family. The same is true of continuous cropping of fields with plants of any other one family.

Crop rotations are most effective against insects that are restricted feeders, that have limited powers of migration or sluggish habits, and that are slow breeders, spending a relatively long time in the feeding stage.

Crop rotations are much less effective against insects that move about freely. Many such insect species are in the field the first year it is planted to a susceptible crop and may occur in numbers sufficient to cause severe damage. Generally, however, infestations in such fields will be later and lighter than in fields continued in the same crop, and therefore crop rotations are still the best, and in some cases almost the only, means of controlling certain insects.

Some common insects and the susceptible crop hosts are shown in Table VI.

Table VI

INSECTS CONTROLLED ENTIRELY OR IN PART BY ROTATIONS

Insect	Susceptible Crop[1/]
Wheat Stem Sawfly	wheat, spring rye
Wheat Stem Maggot	wheat, barley
Hessian Fly	wheat, barley
Wireworms	wheat, oats, barley, spring rye, corn, potatoes and sunflower
	less suscep. - flax, sweetclover and alfalfa
Sweetclover Weevil	sweetclover
European Corn Borer	corn
Sunflower Moth	sunflower

1/ Wheat includes durum

Labor distribution is achieved by rotations that distribute the required load over a longer season. Rotations that include perennial grasses and legumes, fall seeded crops such as rye, late seeded crops such as corn, millet, sudangrass and flax and late maturing crops such as corn, sugarbeets, potatoes and sunflowers all help spread the work load during the seeding and harvest seasons.

EFFECT OF PREVIOUS CROP

The effect of one crop on another in rotation is shown in yield data from the Dickinson Experiment Station and from the Great Plains Field Station, with limited data from the Fargo Station. See Table VII.

These trials were grown without the benefit of commercial fertilizer or manure and without grass, legumes or green manure crops in the rotation. Today's general use of commercial fertilizer might alter these long-time results.

Table VII

Mandan - 20 yrs. (1915-34) spring disked
34 yrs. (1915-48) spring plowed

Dickinson - 44 yrs. (1908-1951) spring plowed
28 yrs. (1924-1951) spring plowed

Corn yield, pounds of fodder and bushels per acre

Preceding Crop	Mandan 34 years		Dickinson 44 years		Dickinson 28 years	
	Fodder	Grain	Fodder	Grain	Fodder	Grain
Corn	3,800	27.0	3,252	19.4	----	----
Spr. Wheat	3,768	26.1	3,522	16.4	3,588	18.5
Oats	3,777	26.6	3,813	19.3	3,521	19.7
Barley	3,832	26.7	3,329	16.6	3,585	19.9
Fallow	3,905	28.5	3,471	21.5	----	----
Millet	----	----	----	----	3,216	17.8
Flax	----	----	----	----	3,155	18.8

Spring wheat yield in bushels per acre

Preceding Crop	Mandan 34 years	Dickinson 44 years	Fargo 1919-1953
Corn	16.7	18.4	27.7
Spr. Wheat	14.9	11.6	17.7
Oats	15.0	13.6	- - - -
Fallow	21.9	19.8	- - - -
Rye	- - - -	- - - -	21.2

Oats yield in bushels per acre

Preceding Crop	Mandan 34 yrs.	Mandan 7 yrs.	Dickinson 44 yrs.
Corn	37.0	34.1	32.9
Spr. Wheat	33.4	30.9	38.4
Oats	29.5	25.2	26.6
Fallow	48.6	45.9	47.2
Flax	- - - -	26.2	- - - -
Alfalfa (2 yrs.)	- - - -	29.2	34.9
Crested Wheatgrass (2 yrs.)	- - - -	- - - -	34.6
Bromegrass (2 yrs.)	- - - -	24.3	- - - -
Sweetclover (2 yrs.)	- - - -	- - - -	31.3

Barley yield in bushels per acre

Preceding Crop	Mandan	Dickinson 44 yrs.	Dickinson 28 yrs.
Corn - spr. disked	21.0 (20 yrs.)	23.4	21.5
Flax - spr. disked	12.3 (20 yrs.)	- - - -	- - - -
Oats	19.5 (34 yrs.)	18.0	16.3
Barley	19.4 (34 yrs.)	18.0	16.0
Fallow	31.9 (34 yrs.)	25.0	24.1

Flax yield in bushels per acre

Preceding Crop	Mandan (20 yrs.)	Dickinson (28 yrs.)
Corn	5.3	5.8

Source: Rotation and Tillage Investigations - Dickinson Experiment Station, Bulletin 383 - May, 1953.

Mimeographed data prepared by NDSU Agronomy Department

In summary, the following statements can be made concerning the effect of one crop on the next in rotation. Keep in mind that the proper use of fertilizer, especially nitrogen, may alter these effects.

Corn - Little or no difference in yield after different crops. Yield is nearly as high following small grain as following corn. Corn does not respond as well to fallow as small grains. This is of value in planning a rotation because (1) small grains yield better following corn than following small grain and (2) small grains respond to fallow better than corn. Corn on fallow may be worthwhile in a drouth year if such can be anticipated.

Wheat - Does best after fallow, next best after corn and does better following oats than after wheat. In a rotation, wheat should follow summerfallow or corn where possible. Continuous wheat should be avoided.

Oats - Can apparently go any place in the rotation except following oats.

Barley - Yields best on fallow or disked corn ground and poorest after spring plowed oats. Note the poor results after flax. Protein may be high on fallow.

Flax - Flax should be followed with either corn or summerfallow especially if late sown. It should not be planted on fallow because it is a poor weed fighter.

Sorghums - Tend to dry out the soil and leave strong nitrogen deficiencies and should be followed either by sorghum, corn or fallow.

Rye - The biggest problem with rye is volunteer rye. It should be followed by feed grains and not by wheat or durum. Early fall plowing followed by later fall tillage kills volunteer rye and makes a good seedbed for flax.

Sunflower and Safflower - Late maturing, drouth tolerant. Put last in rotation.

Field Beans - Take the place of a row crop.

Peas and Tame Mustard - Early maturing crops and can be followed by other crops. Mustard shatters and should be followed with a crop that can be sprayed for volunteer mustard control.

Green Manure Crops (peas, rye, sweetclover) - Have not increased small grain or corn yields except possibly in the Red River Valley area.

Perennial Grasses and Legumes - Data indicate there is little or no justification for including them in short rotations on good cropland except possibly in Red River Valley area. Except on livestock units, they should be grown in long rotation on the least desirable cropland and if possible on soils with favorable subsoil moisture.

Fallow - As a rule of thumb based on a combination of Experiment Station data and Federal Crop Reports, crops on the average respond to summerfallow about as follows: wheat and barley yield is increased one-third, oats and rye yield is increased one-half, and corn gives a small yield response. Response to fallow is lower on soils with low organic matter and low water holding capacity and varies with the general fertility and moisture level.

UNDESIRABLE FEATURES OF ROTATIONS

Rotations involving some crops may require additional capital investment in the farming operation. For example, a row crop such as corn requires special planting, cultivating and harvesting equipment and may require an investment in livestock if the corn is harvested for silage or fodder. Grass and legume crops may require investments in harvesting equipment and livestock. The activity of soil organisms also tends to increase when sod crops are grown in short rotations and this may hasten the breakdown of soil organic matter (humus). Sugarbeets, potatoes and other crops also require extra investments for specialized equipment. Additional new crops may also add to the labor requirements of the farm.

SECTION II.

VALUE OF GREEN MANURE CROPS IN NORTH DAKOTA

Green manure crops add organic residue to the soil and may temporarily increase the nitrogen supply and make certain other minerals more readily available. Longtime studies show they do not help to reduce the organic matter (humus) loss in soils even when used in regular crop rotation. Their greatest value is to improve the soil tilth and for weed control.

Crops commonly used for green manure include sweetclover, field peas, buckwheat and alfalfa. These should be plowed under early in keeping with good fallow practice or in much of North Dakota they may limit the yield of next year's crop instead of benefiting it. Green manure crops may have considerable value in improving the physical condition of fine textured soils.

It is generally considered that only one-half to two-thirds of the nitrogen contained in the legumes is obtained from the atmosphere. The rest of the nitrogen in legume tops and roots is obtained from the soil and does not represent a gain in N from the atmosphere.

The following information (Table VIII) on the nitrogen yield from various legumes is from the University of Minnesota.

Table VIII

NITROGEN YIELD FROM SEVERAL CROPS

Crop and Management (Legumes Properly Inoculated)	Nitrogen Pounds Per Acre
Oats underseeded with legume, oats removed, plowed fall or spring	20 to 40
Sweetclover plowed second year at hay stage	120 to 150
Alfalfa sod plowed after one crop year	120 to 150
Red clover sod plowed after one crop year	120 to 150
Soybeans drilled solid and plowed under at hay stage	60 to 80
Field peas and oats plowed under at hay stage	60 to 80
Soybean-sudan mixture plowed under at hay stage	40 to 60

Source: Agron. No. 11 Farm and Home Fact Sheet - University of Minnesota

Similar data from Iowa and Nebraska are contained in Table IX.

Table IX

NITROGEN YIELD IN POUNDS PER ACRE OF LEGUME GREEN MANURE CROPS

	1/ Iowa (1955-1957) Determined Fall of Year Seeded			2/ Nebraska 1952
	Tops	Roots	Total	Total Nitrogen Produced
Madrid Sweetclover	74	72	146	181
Arizona Alfalfa	--	--	--	76
Indian Alfalfa	49	31	80	---
African Alfalfa	48	27	75	87
Ladak Alfalfa	--	--	--	83
Ranger Alfalfa	34	21	55	69
Kenland Red Clover	40	10	50	---
Ladino Clover	31	5	36	---
Hubam Sweetclover	--	--	--	52
Madison Vetch	--	--	--	96
Hairy Vetch	--	--	--	79

1/ Source: Agron. J. 51:135-137, 1959.
2/ Source: Agron. J. 48:127-131, 1956.

Table X

NITRATE NITROGEN IN 36 INCH DEPTH OF SOIL AND AVERAGE WHEAT YIELDS SWEETCLOVER MANAGEMENT PLOTS , FARGO STATION

	Lb/A Nitrate Nitrogen			Av. Yield
Management The Previous Season	April 1955	May 1956	Av. of 2 years	Wheat 1919-56
Regular Fallow, No Sweetclover	70	165	117	30.8
Sweetclover Plowed Early Cropped to Flax	41	72	56	23.2
Sweetclover Plowed Early Fallowed	110	256	183	30.7
Sweetclover Plowed at Bud Stage Fallowed	159	209	184	31.9
Sweetclover 1st Crop Hay 2nd Crop - Plowed Down at Bud Fallow	110	189	149	29.3
Sweetclover 1st and 2nd Hay Crops Fall Plowed	38	103	70	24.6
Sweetclover 1st Hay Crop 2nd Seed Crop Fall Plowed	35	63	49	23.1

Source: Unpublished data NDSU Soils Department

Research at Iowa showed that nitrogen in legumes is more slowly available than from fertilizer nitrogen. Madrid sweetclover plowed under, yielding 146 pounds of nitrogen, resulted in corn yield the next year similar to that obtained with 100 pounds per acre of sidedressed commercial nitrogen. The other legumes gave corn yields equivalent to less than 50 pounds per acre of fertilizer nitrogen.

Fargo Experiment Station studies have shown that while sweetclover plowed under early for green manure increased available nitrate in the soil profile, this beneficial effect was apparently largely cancelled by the removal of soil moisture. See Table X. Sweetclover allowed to grow two hay crops or a hay and a seed crop resulted in reduced available soil nitrates and presumably still less stored soil moisture, with resulting lower yields when compared with sweetclover plowed under at earlier growth stages and fallowed, or with summerfallow without legumes.

At Fargo, soil moisture determinations have shown that the longer sweetclover occupies the land, the more it reduces the soil moisture. See Table XI. It should be emphasized that these samples were taken in years of relatively high precipitation.

At Dickinson, Mandan, Hettinger and Williston regular summerfallow has produced greater average crop yields than green manure crops plowed down and summerfallowed the rest of the season. See Table XII. The regular fallow plots have been plowed earlier than the green manure plots and may have enabled these plots to store more moisture and release more nitrogen. In years of exceptionally favorable precipitation, the yields of wheat on green manured land have exceeded that from summerfallow. At Edgeley, however, the yields of wheat following green manure exceeded ordinary fallow while oat yields were less on green manure than on fallow, as at the other stations.

Table XI

EFFECTS OF DIFFERENT SYSTEMS OF HANDLING SWEETCLOVER UPON THE SOIL MOISTURE IN FARGO CLAY SOILS. AVERAGE 1939-1943.

	Moisture in % of Dry Wt. of Soil - Late Fall				
	0-6" depth	6"-12" depth	12"-24" depth	24"-36" depth	36"-48" depth
Fallow no sweetclover	35.4	34.0	34.3	32.5	32.7
2nd year sweetclover Plowed at 4"-sown to flax	29.0	30.9	28.6	28.9	29.0
2nd year sweetclover Plowed at 4"-fallow	26.1	35.4	33.7	31.1	30.6
2nd year sweetclover Plowed at 8-12"-fallow	34.2	33.5	33.7	30.3	32.5
2nd year sweetclover 1st crop hay-plowed-fallow	32.1	32.8	32.2	29.8	32.5
2nd year sweetclover 2 hay crops - fall plowed	29.6	30.1	30.7	28.2	28.6
2nd year sweetclover 1 hay - 1 seed - fall plowed	27.0	29.4	29.0	25.0	28.2

Source: Bi-Monthly Bul. Vol. VI, Jan., 1944, pp. 20-21

Over most of North Dakota crops following green manures usually have produced less yield than following regular summerfallow. It is only in years of high rainfall that increased yields are obtained. Reduced yields are attributed to use of soil moisture by the green manure crop. Considering the cost of seed and the usual yield reductions, the use of green manure is generally not recommended.

In the Red River Valley area, especially on heavy and poorly drained soils, increased yields of crops following green manures often are obtained. In this area, legume green manures are beneficial when used in short rotations.

VALUE OF BARNYARD MANURE AND WHERE TO PUT MANURE IN THE ROTATION

Manure varies in nutrient content depending on kind of animal, quality of feed, and care of manure after it is produced. The average nutrient value of various kinds of manure is shown in Table XIII.

Average mixed farm manures have an analysis or fertilizer grade of about 0.5 - 0.25 - 0.5. A ton of such manure contains fertilizer nutrients equal to 100 pounds of a 10-5-10 fertilizer. Manure does not decompose completely the season it is applied. For this reason only 30 to 40 per cent of the nitrogen and phosphorus is considered available from fresh farm manure the first season. Where manure is partly decayed as from feed lots and cattle sheds, 60 to 70 per cent of the N and P are considered available the first season. The potassium is considered 100 per cent available.

Nutrient losses of manure may occur by leaching from poor storage, by volatilization of ammonia nitrogen if spread and allowed to dry before plowing under, and by runoff if spread on snow over frozen soil. Such losses may reduce the fertility value to the crop by one-half.

Another way to evaluate manure is to credit it with the value of the crop increases obtained by its use in the field.

Research has generally shown that when North Dakota soils were first broken out of native sod, crop yield responses to manure applications were small. However, after 30 to 40 years of cropping, fertility becomes more of a limiting factor and crop responses to manure applications become more pronounced. See Table XIV.

Table XII

AVERAGE YIELDS OF SPRING WHEAT AND OATS AFTER GREEN-MANURE FALLOW, CONTINUOUS CROPPING, AND ORDINARY FALLOW AT FIVE LOCATIONS IN NORTH DAKOTA, 1906-51

Location	Period and Crop	Average Yield, Per Acre, After (Previous Crop or Treatment)				
		Green-Manure Fallow				
		Rye	Pea	Sweet-clover	Continuous Cropping	Ordinary Fallow
	1908-51:	Bu.	Bu.	Bu.	Bu.	Bu.
Dickinson, N.D.	Spring Wheat	19.0	19.1	18.3	11.6	20.9
Do	Oats	51.3	40.5	45.4	26.6	47.2
	1906-22:					
Edgeley, N.D.	Spring Wheat	15.3	16.0	14.6	11.4	13.1
Do	Oats	37.1	35.0	33.5	25.8	39.3
	1912-22:					
Hettinger, N.D.	Spring Wheat	(1)	(1)	(1)	15.4	16.9
Do	Oats	29.8	27.2	31.7	32.2	35.4
	1915-34:					
Mandan, N.D.	Spring Wheat	17.6	16.8	16.2	13.0	19.4
Do	Oats	35.4	33.4	34.2	25.6	45.2
	1910-20:					
Williston, N.D.	Spring Wheat	(2)	(2)	(2)	14.4	18.0
Do	Oats	(3)	(3)	(3)	33.4	40.0

(1) Average for rye, peas, and sweetclover was 13.2
(2) Average for rye, peas, and sweetclover was 16.7
(3) Average for rye, peas, and sweetclover was 32.9

Source: Misc. Pub. No. 952 ARS

Table XIII

AVERAGE AMOUNTS AND COMBINED VALUE OF NITROGEN, P_2O_5 AND K_2O IN MANURES FROM DIFFERENT FARM ANIMALS

Kind of Manure	Pounds Per Ton			Value Per Ton*
	N	P_2O_5	K_2O	
Chicken without litter	31.2	18.5	8.4	$4.58
with litter and feed residues	33.8	28.8	15.4	6.07
Dairy Cattle	11.2	4.6	12.0	1.91
Fattening Cattle	14.0	9.3	10.8	2.50
Hog	10.0	6.5	9.1	1.84
Horse	13.8	4.6	14.4	2.24
Sheep	28.0	9.7	24.0	4.31

* Nitrogen at 8 cents, P_2O_5 @ 9 cents and K_2O @ 5 cents per lb. applied

Source: Michigan State University Circular 231 (1961)

In North Dakota, manure should be applied to land that will be planted to corn or will be summerfallowed. These two places in the rotation are considered best for several reasons. Preparation of land for corn or summerfallow comes late in the spring season, fitting in better with time that can be devoted to loading and spreading manure from feed lots or winter storage. Corn is not as subject to lodging from heavy manure applications as small grains. Tillage done for corn or fallow can better control increased weediness often associated with manure applications.

Manure contains a considerable amount of organic matter. This may cause a temporary nitrogen shortage and may also cause surface soil dryness if plowed down. Small grain yields are, therefore, often lower when manure is plowed down directly ahead of planting. Manures have more time and warmer soil temperatures in which to decay and release nutrients when applied ahead of corn or summerfallow than is the case with small grains manured directly. Generally, soils with thin topsoils or low in organic matter will give greatest crop responses to manure applications.

There is some controversy as to whether or not manure is really worth the expense of hauling it onto the field. However, manure has to be removed from lots and sheds and it takes very little extra effort or expense to spread it on the land. Using manure on the fields and rotations nearest to the manure supply minimize the costs of applying it.

Table XIV

RESPONSE TO BARNYARD MANURE

	1912-1956		1954-1956	
At Fargo[1/]	Check	Manure	Check	Manure
Corn yields bu/A	33.3	36.4	56.5	68.4
Wheat yields bu/A	25.1	29.0	26.0	33.6
At Mandan[2/]	1915-1953		1947-1953*	
Corn yields bu/A	26.8	27.8	32.8	38.0
Wheat yields bu/A	15.9	19.1	17.5	26.1

* Four year average - three years omitted because of hail damage.

1/ At Fargo between 7 and 10 tons of manure were applied for corn in a corn - wheat - sweetclover - oats rotation.
2/ At Mandan 20 tons of manure were applied to one crop in the rotation in both 3 year and 4 year rotations.

SECTION III.

PROBLEM SOIL AREAS AND HANDLING GRASSES AND LEGUMES

PROBLEM SOIL AREAS

Strongly saline soils prevent profitable production of annual crops and are best suited in use as grazing land in native vegetation. If native vegetation has been destroyed by attempts to crop such soils, then reseeding to the most salt tolerant of available permanent species is advisable. Soils that are moderately or less saline can usually be profitably cropped part time.

Such salty (saline) soils need special consideration of crop rotations and cropping practices.

1. Do not use fallow in the rotation on soils with a high water table or during periods when water tables are high enough to allow wicking up of water. The year of fallow with no plants growing and using moisture at lower depths in the soil allows for more upward wicking and evaporation of water from the surface and concentration of salts in the surface soil layers. Salty soils with high water tables should be cropped as much of the time as possible to increase the removal of water at lower depths and reduce net upward movement and evaporation of water.

2. Grow alfalfa or sweetclover at frequent intervals in the rotation. While growing, they can intercept more of the upward wicking water before it reaches the soil surface or upper soil layers. These deep rooted crops may lower the water table, allowing more room for percolating rain and snow moisture to move salts downward.

3. Add organic matter such as barnyard manure or use green manure crops and return all possible straw and stubble to the soil. Organic matter seems to reduce or buffer the injurious effects of the salts on crops.

4. Grow crops that are most tolerant of salty soil conditions. Barley grown for grain is more tolerant of salty soil conditions than other grain crops. Generally crops grown for forage are more successful than grain crops. Injury to grain crops often occurs during heading and seed formation. Grain crops grown for forage can be more successful than the same crops grown for grain. Some of the perennial grasses are the most tolerant of salt conditions. Sweetclover and alfalfa are quite salt tolerant when past the seedling stage of growth. See Table XVI.

For additional information refer to Extension Bulletin No. 2, "Salt Affected Problem Soils in North Dakota".

Table XVI

SALT TOLERANCE OF CROPS

(Arranged in general order of tolerance under each heading, with the most tolerant at the top of each list and with tolerance generally declining in going down each list.)

FIELD CROPS

High tolerance crops	Moderate tolerance crops	Low tolerance crops
None has high tolerance. (In occasional years, particularly those with favorable moisture and cool temperatures, the most tolerant crops may do well on soils usually unsuitable for good yields of field crops.)	Sugarbeets (after emergence) Rape Safflower Barley Rye Oats Wheat (hard red spring) Wheat (durum) Sorghum	Corn Flax Soybean Sunflower (seedling) Peas Field Beans Potatoes

FORAGE CROPS

High tolerance crops	Moderate tolerance crops	Low tolerance crops
Tall wheatgrass	Sweetclover Sudangrass	Alfalfa (seedling)
Slender wheatgrass	Millet Sorghum	White Dutch clover
Russian wildrye	Alfalfa (established) Crested wheatgrass	Alsike clover
Western wheatgrass	Bromegrass Canada wildrye	Red clover
Birdsfoot trefoil	Reed canary	

Source: Extension Bulletin No. 2 - "Salt Affected Problem Soils in North Dakota"

Fields having a light sandy or gravelly soil profile tend to be drouthy and subject to wind erosion. They need special handling and cropping. Summerfallow is of little or no value in storing moisture on these soils because of the low water holding capacity. The best adapted annual crops include short season, early maturing small grains that can be grown during the cool and heavy rainfall months of early summer. Drouth tolerant crops such as sorghum, if not planted too thick, may also be adapted.

Where such soils make up a small part of the farm, the best use for them is planting to a suitable grass and legume mixture for hay or pasture use. This solves the erosion hazard as well as the cost of annual cropping.

If these soils are to be cropped on an annual basis, special emphasis must be placed on erosion control. Practices such as strip cropping and field shelterbelts will be needed in addition to tillage and management practices that leave protective surface crop residue during most of the year.

HANDLING GRASSES AND LEGUMES IN ROTATION

Brown[1/] has reviewed research done in the North and Central Great Plains on effects of legumes and grasses used in dryland cropping systems. The following are some of the summary and conclusions from this review:

Effects on soil nitrogen, organic matter and physical condition

When grown for several years, grasses maintain or may increase soil organic matter.

Alfalfa grown for several years usually increases soil nitrogen and organic matter.

Where legumes and grasses are grown for less than two years, chemical and physical effects usually are not measurable.

Several dryland experiment stations have grown legumes and grass for three years in 6-year rotations. Nitrogen and carbon losses from the soil have been reduced compared to non-legume, grass rotations. Reductions in nitrogen losses were due to reduced runoff and erosion and to legume-nitrogen additions.

When grown for several years, grasses decrease bulk density of the surface soil, increase infiltration, improve aggregation and reduce erosion. Effect of legumes on physical condition of the soil appears to be minor.

Data from Kansas, Nebraska, North Dakota and southwestern Saskatchewan indicate that three to five years of grass improves soil structure of some soils.

Beneficial effects of grass appear to be rather short-lived. Data from Mandan, North Dakota indicate that 75 to 95 per cent of grass roots in the surface six inches of soil had decomposed 2½ years after plowing. Structural improvement under grass appears to be considerably slower than structural deterioration after grass is plowed.

Improved soil physical conditions have seldom increased crop yields in the Northern and Central Great Plains. This probably indicates that physical conditions are not limiting crop production.

Effects on soil moisture and yield of following crop

At both Lincoln, Nebraska, and Manhattan, Kansas, alfalfa used soil moisture to at least 30 feet when moisture was available from the surface downward. When deep soil moisture reserves were depleted at Lincoln this moisture was not restored on medium to heavy textured soils under continuous cereal cropping. Five years of continuous fallow rewet the soil to only 11 feet.

At Manhattan, Kansas, cereal cropping restored deep soil moisture reserves after 12 years and fallow after two years in a period of exceptional heavy precipitation.

Sweetclover has been shown to use soil moisture to nine feet in one year and 14 feet in two years. Grasses are comparatively shallow rooted and seldom deplete soil moisture below six feet.

In the drier areas of the chernozem and in all the chestnut and brown soil zones of the United States and Canada, legumes and grasses used as green manure, hay or pasture crops usually depress the yields of the crops immediately following. Yield reductions are commonly associated with depleted soil-moisture reserves. Even if the land is fallowed before planting the following crop, yields are frequently not increased over those with ordinary fallow.

1/ Paul L. Brown. Legumes and Grasses in Dryland Cropping Systems in the Northern and Central Great Plains. USDA ARS Misc. Pub. 952. 1964.

Along the eastern edge of the Northern and Central Great Plains, where annual precipitation is greater, legumes in rotation increase yields of corn and small grain in years of average or above average precipitation. In dry years, grain yields may be depressed by dry soil conditions after legumes. The increased crop yields in areas of higher rainfall are attributed to the addition of nitrogen from the legume rotation. Based on yields of following crops, the average legume inorganic nitrogen equivalent is estimated to be 30 to 40 pounds per acre per year.

From the standpoint of increasing yields of following crops, available data indicate little justification for growing legumes and grasses in short rotation on class I, II and III land in the Northern and Central Great Plains. (See Section IV for land class description.)

Other benefits

Legumes and grasses are effective in reducing wind and water erosion. Excessive erosion eventually decreases yields. Incorporating legumes and grasses in the cropping system is an effective way to reduce soil losses. Legumes and grasses are valuable crops in themselves. They are an essential part of any livestock enterprise.

The following article indicates that the longer soils are cropped in North Dakota the more likely they are to give beneficial yield response to grasses and legumes used in rotation. The article is included in its entirety.

> Haas, J. J. Cropping Systems Influence Wheat and Corn Yields and Nitrogen Levels of Dryland Soils. Journal of Soil and Water Conservation, Vol. 10, No. 3, page 152, May, 1955.

"Crop rotation studies have been conducted at Mandan, North Dakota over a 40-year period by USDA in cooperation with North Dakota Agricultural Experiment Station. These rotations contained practices which had varying degrees of influence upon productivity of the soil. In recent years, crop yields have varied widely and soil fertility has definitely limited yields in the more exhaustive cropping practices. A comparison of relative yields during a four-year period near the beginning of the 40 years of cropping and during a four-year period near the end of that time is shown in Table XVII.

"Average annual precipitation for the first period was 15.7 inches, as compared to 16.7 inches for the last period. With the exception of the continuous cropping treatments, wheat followed corn and the corn followed small grains in all cropping practices. Relative yields of wheat for the first period ranged from 86 to 110 per cent and for the last period from 97 to 149 per cent. Corn yields for the first period ranged from 76 to 111 per cent and for the last period from 68 to 123 per cent. The highest yields were obtained from these rotations containing alfalfa or receiving

application of barnyard manure. Wheat yields from these two cropping systems were 40 and 49 per cent greater, and corn yields were 23 and 16 per cent greater, respectively, than for a rotation with grain crops only.

"Sweetclover growing with the wheat apparently benefitted wheat yields materially, and to a lesser extent corn yields. Grass in the rotation has not benefitted wheat yields materially, but has improved corn yields. Continuous cropping produced the most corn during the first period, but produced the least by far during the last period. With few exceptions, there is a fair relationship between the yields during the last period, and the loss of soil nitrogen during the 40 years of cropping. Those cropping practices which produce the highest yields during the last period lost the least nitrogen. Conversely, those cropping practices which produced the lowest yields lost the most nitrogen.

"It is apparent from these results that soil fertility is limiting crop production on dryland soils of this area where cropping systems have not included legumes or where manure applications have not been made. Thus, it is important to consider soil fertility maintenance as well as moisture conservation in a sound conservation program for these dryland soils.

"It is mainly for these latter reasons grasses and legumes can be recommended and used in rotations in North Dakota. Beneficial effects on yields of succeeding grain crops may be expected most often in the eastern area of highest rainfall, in higher rainfall years throughout the state, and on soils of poor physical condition or low fertility."

With the present availability and low cost of fertilizers coupled with the moisture depleting power of grasses and legumes extensive use of these crops in a dryland rotation may be questionable unless there is a need for the forage produced.

CROPPING AND FERTILIZING AFTER SODS

Land left seeded to sod crops one or two years should, when possible, be followed with a row crop. It may even be successfully cropped to flax or small grain in years of favorable moisture.

When land has been left in sod crop three years or longer, special attention needs to be given to the rotation and fertilizer program. Sod crops considered are grass, alfalfa-grass mixtures and alfalfa. All three kinds of sods are likely to leave the soil low in stored moisture. Alfalfa tends to deplete soil moisture more severely than grasses. In some North Dakota research, alfalfa sod plowed in the fall and seeded to wheat for five successive years following showed definite lack of moisture for the first two seasons, although seasonal rainfall was average and above. Wheat on crested wheatgrass sod alongside showed less lack of moisture and only in the first year after the fall plowed sod. Wheat was grown on wheat stubble in these trials for comparison.

Table XVII

RELATIVE YIELDS OF WHEAT AND CORN FOR TWO PERIODS OF TIME AND CHANGE OF SOIL NITROGEN IN THE 0 TO 6 INCH DEPTH OF SOIL UNDER DRYLAND CROPPING AT MANDAN, NORTH DAKOTA.

Cropping System	Relative Yields[1/] Wheat 1915 to 1918 %	Wheat 1947 to 1953[2/] %	Corn 1915 to 1918 %	Corn 1947 to 1953[2/] %	Changes[3/] in soil Nitrogen %
Grain crops only	100	100	100	100	-34
Grain crops plus grass	86	97	76	110	-30
Grain crops and sweetclover[4/]	105	124	94	110	-30
Grain crops and alfalfa	110	140	97	123	-19
Grain crops plus manure	101	149	94	116	-3
None (Continuous wheat)	96	113	---	---	-18
None (Continuous corn)	---	---	111	68	-42

NOTE: Wheat followed corn and corn followed wheat in all rotations

1/ Rotation of grain crops only used as base.
2/ Four year average, three years omitted because of hail damage.
3/ Based on nitrogen content of virgin sod. Soil analyzed in 1953 after 40 years of cropping.
4/ Sweetclover was grown with wheat and plowed under for green manure the second year.

Moisture is probably of first concern following sod. Without a good recharge of moisture in the broken out sod, there would be poor chances for crop return or from investment in fertilizer.

In order to replenish moisture, summerfallowing the sod land before cropping is usually deemed best, especially if a small grain crop is to be seeded. Crops like wheat, barley and oats need moisture early in the season. If the sod land is not fallowed, corn stands a better chance as its heavy demand for moisture comes later in the growing season and this leaves more time for rains to occur to recharge the soil moisture.

If the sod is broken up July 1, how good a moisture supply would be accumulated would depend on precipitation between July and seeding time the next spring. Breaking the sod May 1 or June 1 would provide greater opportunities for moisture accumulation in the fallow.

In Eastern North Dakota there is a greater chance of having late summer and fall rains that might replenish soil moisture from a July 1 or fall sod breaking than is the case in western North Dakota. The fact remains, however, that May and June are normally heavy rainfall months. Another point is that the sod crop should be killed before it uses up stored soil moisture.

Fertilizer requirements should be determined by soil tests, and an estimation of stored available soil moisture.

Grasses leave highly carbonaceous residues in accumulated top growth and roots. In research done a number of years ago at the Mandan Station around 70 per cent of the grass roots decayed in 1½ years after breaking and about 90 per cent in 2½ years. In decay of this carbonaceous material, the organisms in the soil compete with the crop for available soil nitrogen much as occurs with straw and stubble after a small grain crop. However, the accumulation of unharvested material plus larger amounts of roots following soil bank grass as compared to small grains would tend to make for more residue and a greater nitrogen deficiency in such sods than in small grain stubblelands.

Breaking a grass sod July 1, or later in the summer or fall, would not allow much time for organisms to act on the most easily decayable carbonaceous material. It is expected that in this case nitrogen fertilizer needs would be equal to those recommended for stubbleland.

Breaking grass sod June 1 would more nearly approach regular fallow but the expected greater amount of carbonaceous material would likely call for nitrogen fertilizer treatment equal to about half that of regular stubbleland nonfallow.

Breaking grass sod by May 1 and summerfallowing the rest of the season would likely approach closely the nitrogen status of regular June 1 fallow on stubbleland.

With a good proportion of legumes in the sod mixture (40 per cent or more legume), the ratio of carbon to nitrogen in the residues and roots would not be as large. In the decay of this material, the nitrogen needs of the organisms are more nearly met by nitrogen content within the material and there is less competition with the crop for available soil nitrates. It also would be expected that available nitrates would be released and accumulate more quickly and in greater amounts as the date of breaking out is advanced from fall to July 1 to June 1, and finally to May 1.

For alfalfa grass mixtures broken out of sod July 1 or later, a nitrogen treatment at about half the rate for regular stubbleland nonfallow might be about right.

In any case, the nitrogen needs can be predicted with a nitrate-nitrogen soil test with adjustments made depending on the amount of stored available soil moisture at planting time and for the area of the state in which the field is treated.

For the Red River Valley area, slightly higher nitrogen treatments, and for western North Dakota, slightly lower nitrogen rates would be indicated.

For the East Central area of the state, for example, the nitrogen rates per acre for small grain likely to be best for each condition would be as follows:

Table XVIII

SUGGESTED NITROGEN RATES FOLLOWING SOD CROPS

	Stored Available Soil Moisture at Planting	Broken the Previous Year		
Grass Sod		July 1 or later	June 1	May 1
	Low	10-20	5-10	0-10
	Medium	35-45	15-25	0-10
	High	55-65	30-35	0-10
Alfalfa or alfalfa grass sod				
	Low	5-10	0-10	0
	Medium	10-20	0-10	0
	High	10-30	0-10	0

SECTION IV.

SUGGESTED ROTATIONS

ESTABLISH ROTATION AREAS

Most farms or ranches are large enough that they should first be divided into rotation areas. Each rotation area should be set up on the basis of similar soil type, topography, distance from farmstead and other factors (Section I "Planning Rotations") that will influence the use of the area. Each area should be large enough so that it can be subdivided into as many fields of equal size as there are years in the rotation. For example, a three year rotation requires three fields of equal size. If the area is large enough, two or more rotations, which may be the same or different, can be planned for the area.

PLANNING ROTATIONS

The most productive soils areas should be devoted to the leading cash crops to be grown. These areas also will usually be devoted to the shortest and least flexible rotations.

The less productive soil areas will be devoted to more flexible and likely longer rotations, especially if they contain perennial grasses and legumes.

Unproductive soils areas, large or small, should be retired to permanent grass because they cannot be cropped profitably.

To plan the rotations, refer again to the several previously discussed factors that should be considered in setting up crop sequences. In the final analysis, economic return will govern the kinds of crop to be grown but not the sequence of crops.

LAND CAPABILITY CLASSES

The Soil Conservation Service has developed the following land capability classifications for the United States, based on both soil and climatic factors.

Class I - Soils in Class I have few limitations that restrict their use.

Soils in this class are suited to a wide range of plants and may be used safely for cultivated crops, pasture, range, woodland, and wildlife. The soils are nearly level and erosion hazard (wind or water) is low. They are deep, generally well drained, and easily worked. They hold water well and are fairly well supplied with plant nutrients or highly responsive to inputs of fertilizer and are located in areas where climatic factors allow the growing of a wide range of crops.

In North Dakota, climatic factors limit land use and as a result it is generally assumed that we have no Class I land in this state.

Class II - Soils in Class II have some limitations that reduce the choice of plants or require moderate conservation practices.

Soils in this class require careful soil management, including conservation practices to prevent deterioration or to improve air and water relations when soils are cultivated. The limitations are few and the practices are easy to apply. The soils may be used for cultivated crops, pasture, range, woodland or wildlife.

Limitations of soils of Class II may include singly or in combination the effects of (1) being gently sloping, (2) moderate susceptibility to wind or water erosion, or moderate effects of past erosion, (3) moderate depth, (4) poor internal drainage, (5) slight saltiness (salinity), (6) wetness correctable by surface drainage usually associated with poor surface runoff, (7) climatic limitations, (8) slightly-stony or stony conditions, and (9) fine texture.

Class III - Soils in Class III have severe limitations that reduce the choice of plants or require special conservation practices or both.

Soils in Class III have more restrictions than those in Class II and when used for cultivated crops the conservation practices are usually more difficult to apply and maintain. They may be used for cultivated crops, pasture, woodland, range or wildlife.

Limitations of soils in Class III restrict the amount of clean cultivation, timing of planting, tillage and harvesting, choice of crops or a combination of these items. The limitations may result from the effects of one or more of the following: (1) being moderately sloping, (2) high susceptibility to water or wind erosion, (3) shallow depth, (4) moderately coarse texture, and (5) moderate saltiness (salinity).

Class IV - Soils in Class IV have very severe limitations that restrict the choice of plants, require careful management or both.

The restrictions in use for these soils are greater than those in Class III and the choice of plants is more limited. When these soils are cultivated more careful management is required and conservation practices are more difficult to apply and maintain. Soils in Class IV may be used for crops, pasture, woodland, range or wildlife.

Soils in Class IV are limited for cultivation use as a result of the effects of one or more permanent features such as (1) being strongly sloping, (2) severe effects of past erosion, (3) coarse texture, (4) wetness not correctable by surface drainage, but can be cropped 50% or more of the time, and (5) excessive internal drainage.

Moderately sloping soils with moderately coarse surface texture have a combination of factors placing them in Class IV.

Class V - Soils in Class V have little or no erosion hazard, but have other limitations that are impractical to remove that limit their use largely to pasture, range, woodland and wildlife.

Soils in this class have limitations that restrict the kind of plant that can be grown and that prevent normal tillage of cultivated crop. These often are associated with wetness and have very poor drainage with wet poorly drained profiles. Cropping is possible less than 50% of the time.

Class VI - Soils in Class VI have severe limitations that make them generally unsuited for cultivation and limit their use largely to pasture or range, woodland or wildlife.

Physical conditions of soils placed in Class VI are such that it is practical to apply range or pasture improvements, if needed, such as seeding, liming, fertilizing and water control with contour furrows, drainage ditches, diversions or water spreaders. Soils in Class VI have continuing limitations that cannot be corrected, such as (1) steep or very steep slopes, (2) very shallow depth, (3) severe saltiness (salinity), (4) very severe past erosion, (5) very stony, and (6) very high susceptibility to wind erosion.

Class VII - Soils in Class VII have very severe limitations that make them unsuited for cultivation and that restrict their use largely to grazing, woodland, or wildlife.

Physical conditions of soils of Class VII are such that it is impractical to apply such pasture or range improvements as seeding, fertilizing, etc. Soil restrictions are more severe than those in Class VI because of one or more continuing limitations that cannot be corrected.

Class VIII - Soils and land farms in Class VIII have limitations that preclude their use for commercial plant production and restrict their use to recreation, wildlife, water supply or aesthetic purposes.

Badlands, rock outcrop, sandy beaches, river wash, mine tailings, and other nearly barren lands are included in Class VIII.

ROTATION SUGGESTIONS

The following rotation suggestions are set up as general guide lines for three general areas of the state and for different types of cropland that may be found on different types of farms in each area.

WESTERN NORTH DAKOTA

Crop Key - Small grains include wheat, oats, barley and rye
Row crops include corn and sorghum

A - Cash grain farms

For Land Capability Classes I, II, III & IV

2 year: fallow - small grain
3 year: fallow - small grain - small grain (or flax in some areas)

For Land Capability Classes VI, VII

Retire to permanent grass - include native grasses in seeding mixture

B - Mixed livestock and cash crop farms

For Land Capability Classes I, II, III

2 year: corn - small grain
3 year: fallow - small grain - small grain (or flax in some areas)
3 year: corn - small grain - small grain
4 year: fallow - small grain - row crop - small grain

For Land Capability Class IV

5 to 8 year: fallow - small grain - small grain (with grass legume seed) - grass legume (2 to 5 years)

For Land Capability Class VI & VII

Retire to permanent grass - include native grasses in seeding mixture

C - Livestock and no cash crop farms

For Land Capability Class I & II

Continuous: corn
2 year: corn - small grain

Maintain all other land capability class in tame or native sod

CENTRAL NORTH DAKOTA

Crop Key - Small grains include wheat, barley, oats and rye
Row crops include corn, sorghum and soybeans where adapted

A - Cash grain farms

For Land Capability Class I, II, III

3 year: fallow - small grain - small grain or flax
4 year: fallow - small grain - small grain - flax
4 year: fallow - small grain - row crop - flax

For Land Capability Class IV

Continuous: small grains

For Land Capability Class VI & VII

Retire to permanent grass - include native grass in seeding mixture

B - Mixed livestock and cash crop farms

For Land Capability Class I, II, III

3 year: fallow - small grain - small grain or flax
4 year: row crop - small grain - row crop - small grain or flax
4 year: fallow - small grain - row crop - small grain or flax
5 year: fallow - small grain - row crop - flax - millet or sudangrass
6 year: row crop - small grain (with grass & legume seed) - grass and legumes (2 years) - fallow - small grain (eastern counties only)

For Land Capability Class IV

7 year: fallow - small grain (with grass & legume seed) - grass and legume (5 years)

For Land Capability Class VI & VII

Retire to permanent grass - include native grass in seeding mixture

C - Heavy livestock farms

For Land Capability Class I, II, III

2 year: corn - small grain
3 year: row crop - small grain - small grain
4 year: fallow - small grain - row crop - small grain
5 year: fallow - small grain - small grain (with grass & legume seed) - grass and legumes (2 years)

For Land Capability Class IV

7 year: fallow - small grain (with grass & legume seed) - grass and legume (5 years)

For Land Capability Class VI & VII

Retire to permanent grass - include native grasses in seeding mixture

RED RIVER VALLEY AREA

Crop Key - Small grains include wheat, barley and oats
Row crops include corn, sorghum and other row crops as indicated

A - Cash crop farms

For Land Capability Class I, II, III, IV

3 year: corn or potatoes - small grain - small grain or flax
4 year: fallow - sugar beets - small grain - small grains (with sweetclover seed)
4 year: small grain - sugar beets - small grain - small grain
4 year: row crop - small grain - soybeans - small grain or flax
4 year: fallow - small grain - soybeans - small grain
5 year: fallow - small grain - small grain - soybeans or other row crop - flax
5 year: row crop - small grain - small grain - soybeans or other row crop - flax

For Land Capability Class VI

Retire to permanent grass - include native grass in seeding mixture where practical

B - Mixed livestock and cash crop farm

For Land Capability I, II, III

3 year: row crop - small grain (with clover seed) - clover for hay
4 year: row crop - small grain - small grain (with clover seed) - clover for hay
4 year: row crop - small grain - small grain - sudangrass or millet
5 year: row crop - small grain - small grain (with grass & legume seed) - grass and legume (2 years)

For Land Capability Class IV

7 year: fallow or row crop - small grain (with grass & legume seed) - grass and legume (5 years)

For Land Capability Class VI

Retire to permanent grass - include native grass in seed mixture where practical

C - Heavy livestock farms

For Land Capability Class I, II, III

2 year: row crop - small grain
3 year: row crop - small grain - small grain
5 year: fallow or row crop - small grain - small grain (with grass & legume seed) - grass and legume (2 years)

For Land Capability Class IV

7 year: fallow - small grain (with grass & legume seed) - grass and legume (5 years)

For Land Capability VI

Retire to permanent grass - include native grass in seeding mixture where practical

SPECIAL PURPOSE ROTATIONS - STATEWIDE

1 year: to replace one crop year in regular rotation

a - For wild oats control: rye on summerfallow
b - For general weed control or emergency crop: late planted crops such as millet, sudangrass, flax, sorghum or corn.

ROTATION WORK SHEET

The rotation work sheet which follows on the next page is designed to help the farm operator (1) to outline rotation areas on his farm and (2) to plan a specific rotation for each area.

PROCEDURE

If the farm is too large in size or its shape does not fit the outline maps, use additional sheets for mapping but list rotations for entire farm together on one page.

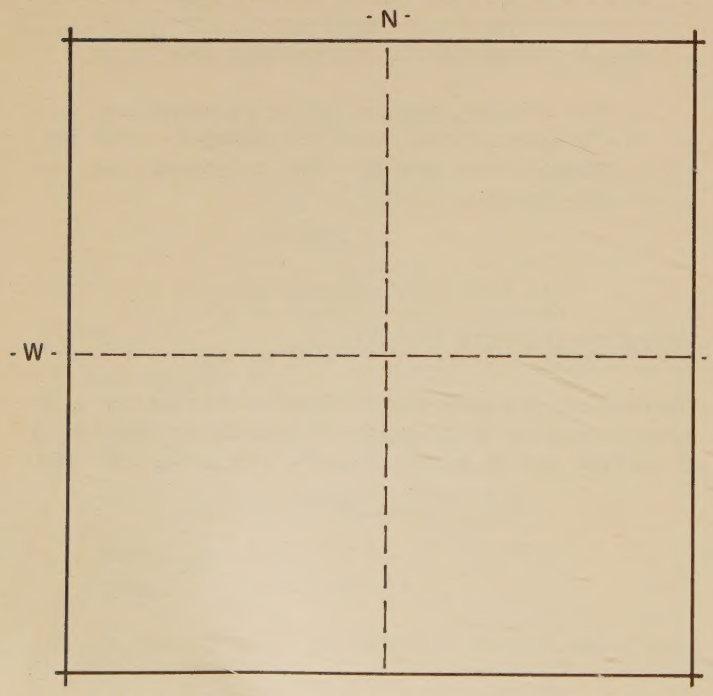
Locate on the map or maps by drawing in: roads, farmstead, fence lines, shelterbelts, streams, native grass, other natural features.

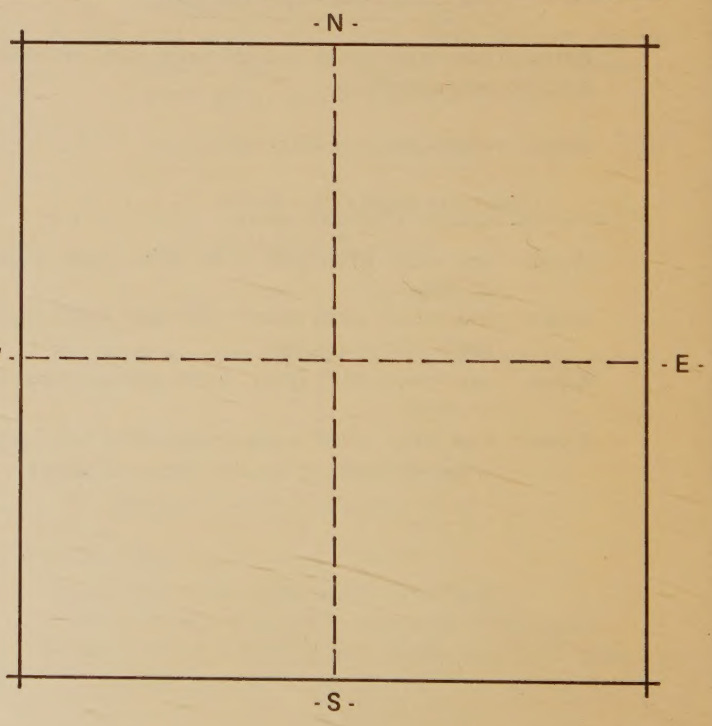
Draw in rotation areas, based on similarity. Use soil maps if available. Assign each area a number - Area I, Area II, etc.

NOTE: Use different colored pencils or markings to outline above features on map.

PLANNED ROTATIONS: If two rotations are planned in separate parts of an area, show as a and b and designate on map.

	No. yrs.	No. acres	Crops 1st yr.	2nd yr.	3rd yr.	4th yr.	5th yr.	6th yr.	7th yr.
Area I									
Area II									
Area III									
Area IV									
Area V									





640 acres Legal description:

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